Modelling fuel and energy supply for central and regional levels of Latvia

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Abstract: - The overall aim of power industry is to provide a well-balanced, qualitative and secure provision of energy to customers. On one hand, the specific of Latvian power industry is its high dependency on the imported resources. At the same time, the level of usage of the renewable energy resources is high. In order to be able to successfully plan power industry policy and to balance the usage of energy resources, it is necessary to analyse the overall power industry development of the country, paying special attention to regional differences. Several potential state and regional development scenarios have been drawn up in the paper.

Key-Words: - modelling, simulation, energy, energy system, electricity, heat, fuel, balance, regional

1 Introduction

In order to develop different energy and fuel production and consumption scenarios in Latvia and to compare them, MESAP program was used [1].

The **M**odular **E**nergy **S**ystem **A**nalysis and **P**lanning (MESAP) software has been designed as a decision support system for energy and environmental management on a local, regional or global scale. MESAP consists of a general information system based on relational database theory, which is linked to different energy modelling tools. In order to assist the decision making process in a pragmatic way Software supports every phase of the structured analysis procedure (SAP) for energy planning. MESAP offers tools for demand analysis, integrated resource planning, demand – side management and simulation or optimization of supply systems. In addition, program can be used to set up statistical energy and environmental information systems to produce regular reports such as energy balances and emission inventories.

The main design principles are:

- centralized data management with a standardized data interface and information system capabilities;
- flexibility in the time and regional scale;
- availability of different suitable mathematical methodologies for different scopes of analysis;
- user friendliness concerning data entry, consistency checking and report generation;
- decision support for the scenario technique through transparent case management.

MESAP is based on an independent database management system. Database collects and stores all data necessary for the modelling process. Database is one of the basic elements or module layers. System includes several modules that can be used for energy planning and analysis. With the help of module PlaNet (see. Fig.1), using the built-in scenario technology, the possible development of the energy system can be simulated. Modelling of energy development scenarios in Latvia used this module.

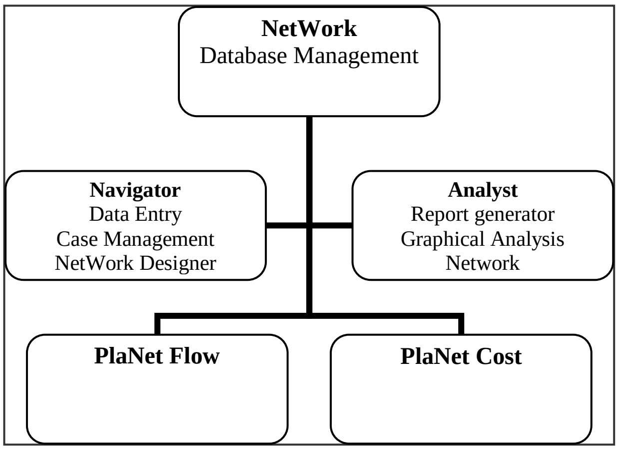

Fig. 1 PlaNet modelling architecture

Time Series Navigator allows the definition of time series, creation, update, and documentation of data values. Case Manager allows creation, description, and registration of scenarios, and to carrying sensitivity analysis. For visualisation of results, creation of tables and graphs, Analyst module is used. Input data and the results can be imported and exported from/to MS Excel.

Simulation modules PlaNet-Flow and PlaNet-Cost calculate energy and emission balance for any energy system and the necessary capacities for energy transformation technologies. Cost calculation module is able to calculate annual necessary investments, fuel costs, fixed and variable costs for each technology, as well as specific production costs. It allows calculation of all costs of energy systems.

After entering input data, the module creates the equations necessary for energy flow calculation.
Energy sector topology in the form of a network structure is defined by **RES** (Reference Energy System) (see Annex). RES structure gives access to the database. RES contains information on the structure of the energy system, but it has no information on modelling equations. This allows strict separation of studies of alternatives and modelling equations. Data can be managed knowing in which model's equations they will be used. Thus one and the same information can be used in different models. RES structure shows the following primary energy and fuel resources: wind energy; hydro energy; imported natural gas; imported heavy oil; imported coal; imported diesel; imported gasoline; wood fuel; peat fuel; and imported electricity.

Process *Gas stocks* shows accumulation and distribution system of natural gas and is described by a factor that includes transport losses. The model allows creation of diesel, heavy oil, and gasoline security stocks for the case of crises. The respective processes in RES structure are "Heavy oil stocks", *Diesel stocks*, and *Gasoline stocks*. The amount of stocks can be altered by changing the factor, which is equal to 1 if no stocks are established. These processes make new energy flows - natural gas, heavy oil, diesel, and gasoline.

The next block in RES structure consists of the processes the transformation of fuel and energy into energy of another type – production of electricity, production of heat in district heating systems. Existing CHP plants of Riga are two separate process, and CHP plants of other towns and of industries are combined in one process. Other processes are hydro power plants of Daugava Cascade, small hydro power plants, wind power plants, and boiler plants. Boiler plants are classified according to fuel type, and there is a separate process for each fuel described by the average efficiency of the respective fuel.

The RES structure includes construction of new CHP plants and the potential condensation CHP plant. In the model, the condensation plant can use natural gas, coal, heavy oil, or peat. There is also a possibility to plan a CHP block for this plant. New CHP plants can use both heavy oil and natural gas; steam and gas turbines and the combined cycle can be described by specific. In RES scheme electricity imports is a separate process described by coefficient 1, as no energy transformation takes place. Secondary energy flows include heat produced in district heating systems and electricity (produced in Latvia and imported). Under electricity flow, there is electricity distribution process described by a coefficient that includes transport and distribution losses. Similarly with heat – its distribution process is described by a coefficient that includes transport and distribution losses. End consumption of electricity and heat is indicated for four consumer groups: industry, households, transport, and other consumers (agriculture, forestry, fishery, construction etc.).

The end consumption of primary energy resources not used in energy conversion processes is classified in four groups: end consumption in industry; end consumption in households; end consumption in transport; and end consumption by other consumers.

2 Fuel and energy balance of Latvia

The primary consumption in Latvia is secured by the local and renewable (wood, peat, straw, hydro resources, wind, biomass) and imported (oil products, natural gas, coal) energy resources. Latvia is dependent on the import of primary resources In 2004 the consumption of primary resources was 199.4 PJ and only 35% of it was covered by local energy resources.

Table 1 Fuel and Electricity Consumption, 1990 and 2004, PJ [2], [3], [5]

Energy resource	1990	2004
Oil products	145,2	57,6
Coal	26,1	2,6
Peat	4,4	0,7
Natural gas	110,7	62,0
Wood	27,6	57,4
Hydroenergy	16,2	11,4
Electricity import	12,9	7,5
Total	**343,1**	**199,1**
Domestic	48,2	69,4
Import	294,9	129,7
Domestic	14%	35%
Import	86%	65%

Since 1990, by increasing the amount of fuelwood for thermal energy production, the dependency on primary resource import has decreased from 86% to 65%.

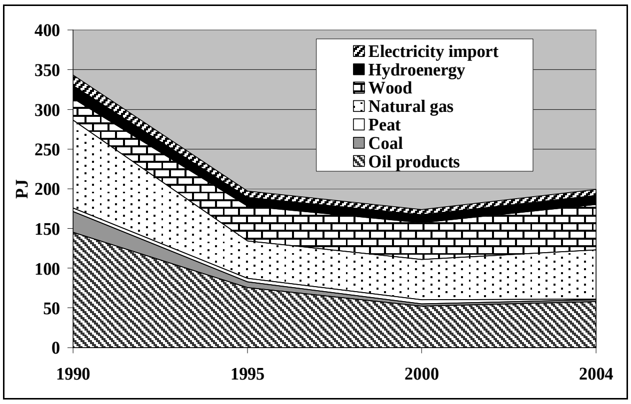

Fig. 2 Fuel balance 1990-2004, PJ [5]

Renewable energy resources take significant place on the primary energy resources balance (33% in 2004), but there is still some unclaimed potential, usage of which could contribute to decreasing the dependency from the imported energy resource.

Considering the fuel and power balance of Latvia for 2004, it can be seen, that there are three dominating types of energy resources – natural gas, wood and oil products. Oil products (petrol, diesel) are mostly used in transportation. The whole potential of wood resources is used. The use of natural gas in power industry has positive characteristics from the environmental and technological point of view, but natural gas is a fuel material conceiving high risk, as there is dependency from a singe supplier – Russia.

3 Prognosis of fuel and energy demand

The following relevant data need to be entered into the model:

- Electricity consumption;
- Heat consumption;
- End consumption of fuel.

Data from the report describe the following infrastructures using fuel:

- Energy conversion;
- Industry;
- Households;
- Others (service, agriculture, building etc.).

In the electricity balance of Latvia, hydro energy takes the major share [8]. The amount significantly varies depending on the climate (35-65%). The proportion of electricity import has been fluctuating recently (2000.-2005.) between 35-45% (see Fig. 3).

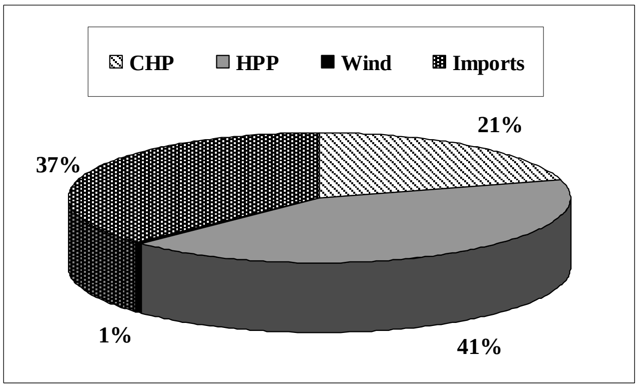

Fig. 3 Electricity Production, 2004, PJ [4]

Electricity balance of Latvia in the last 15 years is presented in Fig. 4.

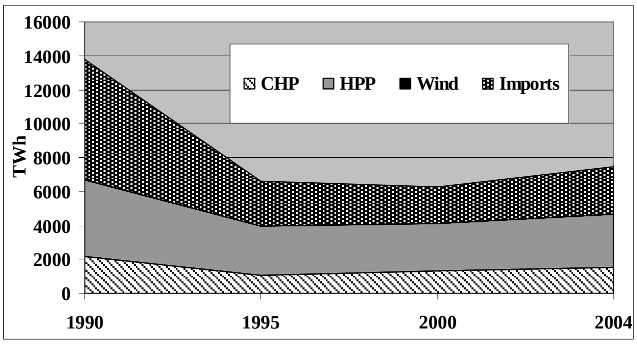

Fig. 4: Electricity Balance of Latvia, 1990 - 2004, PJ [5]

If compared to developed countries of Europe, the power consumption of Latvia is low. But the analysis of potential demand forecast and basing on the developed scenarios of economic development

[2], [6], it can be concluded, that power consumption up to 2010 will increase by approximately 3-8% year.
The model assumes that the consumption of power will increase by 4.5% a year (see Fig. 5).

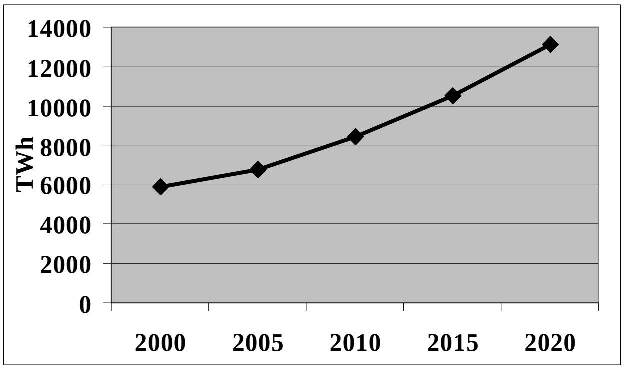

Fig. 5: Prognosis of electricity demand in Latvia, 2005 - 2020, TWh [2], [6]

Prognosis says that the heat demand (Fig. 6) could decrease by about 40% in the period 2000 to 2020.

There are two basic reasons:

1. Decrease of the heat load connected to district heating systems.
2. Efficient heat consumption will be reduced significantly by installation of automatic regulation in heat substations. The process is already ongoing, and it will even speed up. Consumption of domestic hot water will be the first to decrease, as installation of hot water regulation equipment requires less resource. Efficient heat consumption for heating will fall when independent heating connection will gradually replace current system. Energy efficiency measures in building constructions will also contribute to the reduction of heat consumption.

Current development tendencies show that end consumption of fuel in industry will not change significantly in the modelling period, as neither rapid growth nor decrease in production is expected.

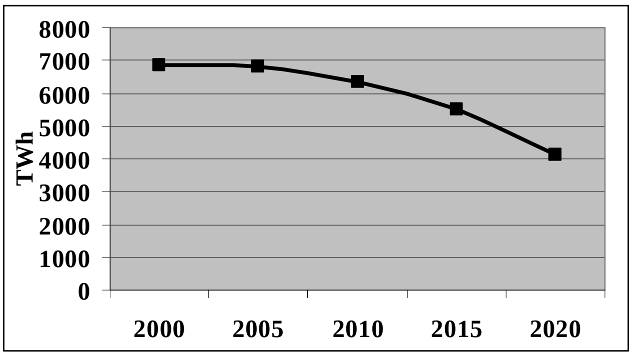

Fig. 6 Prognosis of heat demand in Latvia, 200.-2020, TWh

End consumption in households will rise due to two factors:

- increase in living standard. People will not limit their consumption so much;
- part of the consumers using district heating will disconnect and install their own local heat sources.

End consumption by other consumers will also increase due to:

- new consumers;
- a significant part of consumers of this sector will choose local heat supply.

4 Possible development scenarios

The modelling period accepted is years 2005 to 2020.

Following scenarios were chosen for further modelling:

1. Base scenario (I);
2. Maximal use of RES (renewable energy resources) and domestic energy resources (II);
3. Fuel diversification scenario (III).

In case of base scenario, the power supply industry retains the installed capacities, but the outstanding amount is being imported.

The local energy resource scenario envisages usage of local peat, wind energy and wood. Carrying out scenario simulation it is assumed that the total capacity of installed wind generators is 200 MW. Besides, usage of wood for production of power has been initiated (so far wood has only been used for thermal energy production) by installing new capacities of approximately 50 MW [7]. Similar capacities (50 MW) are also installed for peat usage in power plant.

In the scenario of fuel material diversification, the main emphasis is put on the usage of coal in the newly erected condensation power plants with total 400 MW capacity.

5 Results of development scenario simulations

Carrying out the simulation for thermal energy, power and end energy consumption has been assumed to be constant for all scenarios.

The results obtained are the amounts of necessary primary resource supplies, which vary for each of the scenarios. The results are demonstrated in Fig. 7 – Fig. 9.

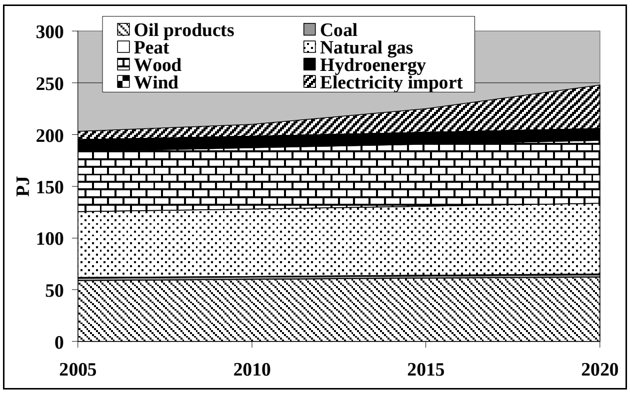

Fig. 7: Results of Base scenario, PJ

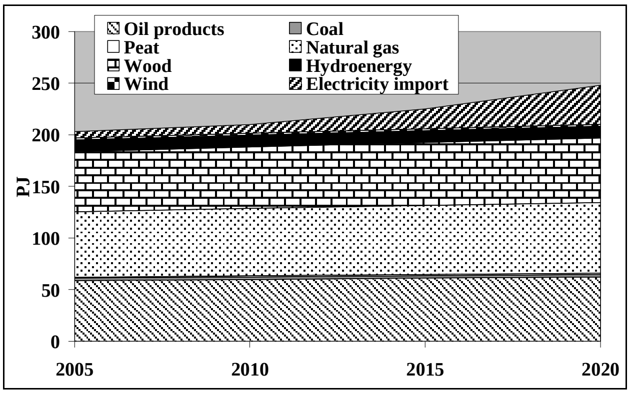

Fig. 8 Results of RES scenario, PJ

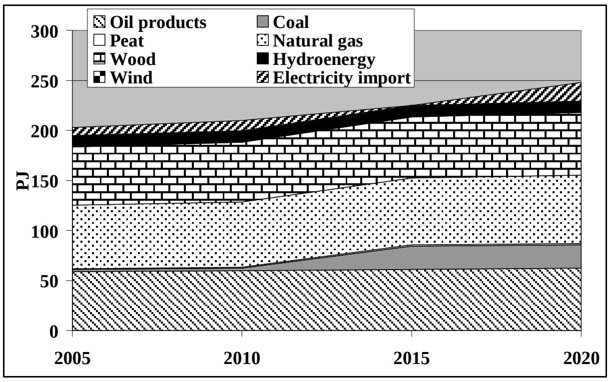

Fig. 9 Results of fuel diversification scenario, PJ

6 Regional modelling

RES structure of energy system can be freely described, as there are no limits for neither processes, flows, nor their connections. Additional function of the model – division into regions – allows more precise application of this structure for the purpose of the specific model. Since RES structure is the basis of the database, it cannot be changed when the modelled area is divided into regions. Only the data describing regions are changed in modelling. Technologies or processes that are not used in some regions can be excluded by assigning a zero value.

Latvia is divided into the following 6 regions:

- Centrs region;
- Kurzeme region;
- Zemgale region;
- Latgale region;
- Vidzeme region;
- Ziemeļvidzeme region.

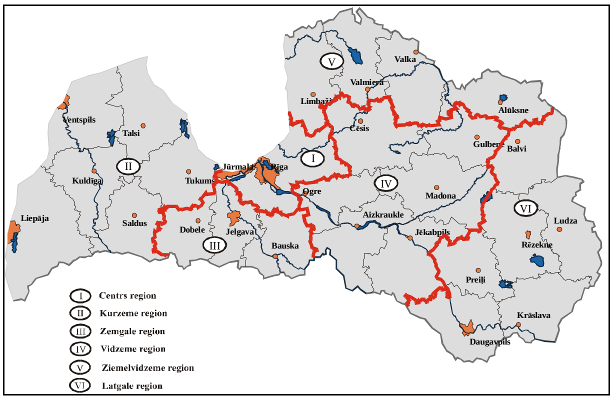

Fig. 10 Regions of Latvia

Fig 10 demonstrates Latvia division into regions. In this division, the following factors have been taken into account:

1. Geographical location of regions.

The traditional regional division of Latvia – Kurzeme, Latgale, Vidzeme, and Zemgale – is used as the basis. Vidzeme is subdivided into Vidzeme and Ziemeļvidzeme regions, as the territory of Vidzeme region is much larger than others, and this is inconvenient for comparison of the results. Centrs is taken as a separate region (3474 square kilometres which is 5 % of the territory of Latvia). This region includes Riga, Riga district with 7 towns, 17 rural municipalities, and resort town Jurmala. Centrs significantly differs from other regions with population density – there live more than million people, which is equal to 41% of the total population of the country.

2. Structure of available fuel and energy types.

E.g. there are significantly less wood resources in Zemgale than in other regions, but Vidzeme, Ziemelvidzeme and Kurzeme are rather rich in wood resources. The same pattern appears with natural gas availability – in Centrs and Zemgale region, natural gas is far more available than in other regions. There is more peat in Latgale, Vidzeme, and Ziemelvidzeme.

3. Structures created by local governments of second level, and cooperation activities.

In Ziemelvidzeme and Zemgale, cooperation agreements are concluded among local governments providing common activities.

Centrs must be considered separately, as its economic activity significantly differs from other regions – it is much broader and more intense. This region is the main administrative, industrial, transport, financial, educational, and trade centre in Latvia. Major science, education, and culture institutions are situated there. Riga regional development council has started strategic planning process with a view to facilitate development of each municipality of the region and identify objectives, priorities, and tasks of Riga region as the new development region of the Baltic Sea.

The results of the modelling on the regional level are demonstrated in Fig. 11.

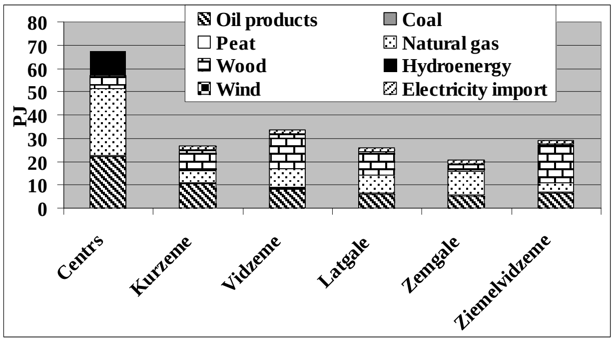

Fig. 11 Results of base scenario (regional)

7 Conclusions

The obtained simulation results show, that the increasing demand for power can be addressed in several ways – by continuing to import power, maximally using the renewable and local energy resources, as well as using coal for the production of power.

As a decrease of generating capacities is anticipated in Baltics after 2010 (shutting down of Ignalin Nuclear power plant in Lithuania, great depreciation of existing capacities) and the Baltics are isolated from other EU markets, installing of new generating capacities in Latvia is necessary. As shown in Fig. 8, the local energy resources can not satisfy the increasing demand.

For a certain period of time, a solution for power supply industry in Latvia is a construction of new coal power plants, which tackles two problems at a time – decreases the dependency from natural gas supplies and allows to decrease the amount of power import (see Fig. 9). Still, also these power plant capacities can be scooped in future by the increasing demand (after 2020), so a coherent power supply planning for the region is necessary.

From the modelling at the regional level, it can be concluded that:

1. The consumption of fuel and energy in the central region builds up 40% of all the amount used by other regions.
2. The fuel types used depend on the region: the natural gas is used in central Latvia and Zemgale region. Ziemelvidzeme and Vidzeme regions mainly use wood. Such distribution is explained by the location of natural gas mains, the availability of wood and location of wood transportation transit roads.
3. The usage of oil products is nearly equal in all regions. Oils are mainly used in transport sector, while only 4-5% of total oil product consumption are used for power industry.
4. Production of power is concentrated in central region – approximately 90% of total amount is produced there.

Further modelling is projected on development scenarios which would balance out the usage of different types of fuel and energy not only centrally, but also at regional level.

MESAP model has been used for development of several projects within the PHARE programme framework [9], [10]. The results obtained have been used in development of scenarios for power industry policy of Latvia.

This paper is based on elaboration foreruns carried out during the above mentioned projects, widening the research framework and modelling conditions.

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